1993

Chapter 1 The Enigma of Drought

Donald A. Wilhite
University of Nebraska - Lincoln, dwilhite2@unl.edu

Published in *Drought Assessment, Management, and Planning: Theory and Case Studies*, edited by Donald A. Wilhite, chap. 1, pp. 3–15 (Boston: Kluwer Academic Publishers, 1993).

Chapter 1

The Enigma of Drought

Donald A. Wilhite

Introduction

Drought is the most complex and least understood of all natural hazards, affecting more people than any other hazard (Hagman, 1984). For the past several decades, we have been reminded again and again of the ravages of drought and the inability of most societies to effectively mitigate impacts in the short term and reduce vulnerability in the longer term. In fact, most scientists would agree that vulnerability to drought is increasing for a number of reasons, the most important of which may be the increasing pressure of an expanding population base on limited water and other natural resources.

The purpose of this chapter is to lay the foundation for an understanding of the concept of drought. The primary emphasis of the chapter will be on understanding the concept of drought and why, according to Hagman (1984), the phenomenon is not better understood by scientists and policy makers. Drought is a normal part of climate and its recurrence, like other extreme climatic events, is inevitable. Through a better understanding and awareness of the characteristics of drought and its differences from other natural hazards, both scientists and policy makers will be better equipped to establish much-needed policies and plans whereby vulnerability can be reduced or stabilized for future generations.

Drought: An Overview

Drought differs from other natural hazards (e.g., floods, tropical cyclones, and earthquakes) in several ways. First, since the effects of drought often accumulate slowly over a considerable period of time and may linger for years after the termination of the event, a drought's onset and end are difficult to determine. Because of this, drought is often referred to as a "creeping phenomenon" (Tannehill, 1947). Second, the absence of a precise and universally accepted definition of drought adds to the confusion about whether or not a drought exists and, if it does, its degree of severity. Realistically, definitions of drought must be region and application (or impact) specific. This is one explanation for the scores of definitions that have been developed. Unfortunately, many of these definitions have not adequately defined drought in meaningful terms for scientists and policy makers. This is the result, at least in part, of misunderstandings of the concept by those formulating definitions. Third, drought impacts are less obvious and are spread over a larger geographical area than are damages that result from other natural hazards. Drought seldom results in structural damage. For these reasons, the quantification of impacts and the provision of disaster relief are far more difficult tasks for drought than they are for other natural hazards. These characteristics have hindered the development of accurate, reliable, and timely estimates of drought severity and impacts and, ultimately, the formulation of drought contingency plans by most governments.

Drought is a normal part of climate for virtually all climatic regimes. It occurs in high as well as low rainfall areas. Drought differs from aridity in that the latter is restricted to low rainfall regions and is a permanent feature of the climate. Many people associate the occurrence of drought with the Great Plains of North America, east Africa, west African Sahel, India, or Australia; they may have difficulty visualizing drought in Southeast Asia, Brazil, western Europe, or the eastern United States, regions perceived by many to have a surplus of water. For example, residents of many humid regions often refer to "green droughts" (i.e., droughts associated with apparent ample rainfall but reduced agricultural productivity because of poor timing of rains or ineffective precipitation). Thus, the character of drought is distinctly regional, reflecting unique meteorological, hydrological, agricultural, and socioeconomic characteristics.

Drought is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length, although other climatic factors (such as high temperatures, high winds, and low relative humidity) are often associated with it in many regions of the world and can significantly aggravate the severity of the event. Drought is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness of the rains (i.e., rainfall intensity, number of rainfall events).

Drought severity is dependent not only on the duration, intensity, and geographical extent of a specific drought episode but also on the demands made by human activities and vegetation on a region's water supplies. The characteristics of drought, along with its far-reaching impacts, make its effects on society, economy, and environment difficult, though not impossible, to identify and quantify. The significance of drought should not be divorced from its societal context. The impact of a drought depends largely on societal vulnerability at that particular moment. Subsequent droughts in the same region will have different effects, even if they are identical in intensity, duration, and spatial characteristics.

Drought Types and Definitions

Because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines. In addition, because drought occurs with varying frequency in nearly all regions of the globe, in all types of economic systems, and in developed and developing countries alike, the approaches taken to define it also reflect regional differences as well as ideological differences. Impacts also differ spatially and temporally, depending on the societal context of drought. A universal definition of drought is an unrealistic expectation.

Definitions of drought can be categorized broadly as either conceptual or operational (Wilhite and Glantz, 1985). Conceptual definitions are of the "dictionary" type, generally defining the boundaries of the concept of drought, and thus are generic in their description of the phenomenon. For example, the American Heritage Dictionary (1976) defines drought as "a long period with no rain, especially during a planting season." Operational definitions attempt to identify the onset, severity, continuation, and termination of drought episodes. Definitions of this type are often used in an "operational" mode. These definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. An operational definition of agricultural drought might be one that compares daily precipitation to evapotranspiration (ET) rates to determine the rate of soil water depletion and then expresses these relationships in terms of drought effects on plant behavior at various stages of development. The effects of these meteorological conditions on plant growth would be reevaluated continuously by agricultural specialists as the growing season progresses.

Many disciplinary perspectives of drought exist. Each discipline incorporates different physical, biological, and/or socioeconomic factors in its definition of drought. Because of these numerous and diverse disciplinary views, considerable confusion often exists over exactly what constitutes a drought (Glantz and Katz, 1977). Research has shown that the lack of a precise and objective definition in specific situations has been an obstacle to understanding drought, which has led to indecision and/or inaction on the part of managers, policy makers, and others (Wilhite et al., 1986). It must be accepted that the importance of drought lies in its impacts. Thus definitions should be region and impact or application specific in order to be used in an operational mode by decision makers. A comprehensive review of drought definitions and indices can be found in a technical note published by the World Meteorological Organization (WMO) (1975). Consult Subrahmanyam (1967), Glantz and Katz (1977), Sandford (1979), Dracup et al. (1980), and Wilhite and Glantz (1985) for a thorough discussion of the difficulties in defining drought.

Drought can be grouped by type as follows: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz, 1985). Meteorological drought is expressed solely on the basis of the degree of dryness (often in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. For example, some definitions differentiate meteorological drought on the basis of the number of days with precipitation less than some specified threshold. Such a definition is unrealistic in those regions in which extended periods without rainfall are common. Other definitions may relate actual precipitation departures to average amounts on monthly, seasonal, water year, or annual time scales. Definitions derived for application to one region usually are not transferrable to another since meteorological characteristics differ. Human perceptions of these conditions are equally variable. Both of these points must be taken into account in order to identify the characteristics of drought and make comparisons between regions.

Hydrological droughts are related more to the effects of periods of precipitation shortfall on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater) than to precipitation shortfalls (Dracup et al., 1980; Klemeš, 1987). Hydrological droughts are usually out of phase or lag the occurrence of meteorological and agricultural droughts. Meteorological droughts result from precipitation deficiencies; agricultural droughts are largely the result of soil moisture deficiencies. More time elapses before precipitation deficiencies show up in components of the hydrological system (e.g., reservoirs, groundwater). As a result, impacts are out of phase with those in other economic sectors. Also, water in hydrological storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., power generation, flood control, irrigation, recreation), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought, and conflicts between water users increase significantly.

The frequency and severity of hydrological drought is often defined on the basis of its influence on river basins. Whipple (1966) defined a drought year as one in which the aggregate runoff is less than the long-term average runoff. Low-flow frequencies have been determined for many streams. If the actual flow for a selected time period falls below a certain threshold, then hydrological drought is considered to be in progress. However, the number of days and the level of probability that must be exceeded to define a hydrological drought period is somewhat arbitrary. These criteria will vary between streams and river basins.

Agricultural drought links various characteristics of meteorological and hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and so forth. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. An operational definition of agricultural drought should account for the variable susceptibility of crops at different stages of crop development. For example, deficient subsoil moisture in an early growth stage will have little impact on final crop yield if topsoil moisture is sufficient to meet early growth requirements. However, if the deficiency of subsoil moisture continues, a substantial yield loss may result.

Finally, socioeconomic drought associates the supply and demand of some economic good or service with elements of meteorological, hydrological, and agricultural drought. Some scientists suggest that the time and space processes of supply and demand are the two basic processes that should be included in an objective definition of drought (Yevjevich, 1967). For example, the supply of some economic good (e.g., water, hay, hydroelectric power) is weather dependent. In most instances, the demand for that good is increasing as a result of increasing population and/or per capita consumption. Therefore, drought could be defined as occurring when the demand exceeds supply as a result of a weather-related supply shortfall (Sandford, 1979). This concept of drought supports the strong symbiosis that exists between drought and human activities. Thus, the incidence of drought could increase because of a change in the frequency of the physical event, a change in societal vulnerability to water shortages, or both. For example, poor land-use practices such as overgrazing can decrease animal carrying capacity and increase soil erosion, which exacerbates the impacts of and vulnerability to future droughts. This example is especially relevant in semiarid regions (e.g., Australia) and in areas of hilly or sloping terrain (e.g., Lesotho).

Drought Characteristics and Severity

Droughts differ from one another in three essential characteristics—intensity, duration, and spatial coverage. Intensity refers to the degree of the precipitation shortfall and/or the severity of impacts associated with the shortfall. It is generally measured by the departure of some climatic index from normal and is closely linked to duration in the determination of impact. The simplest index in widespread use is the percent of normal precipitation. With this index, actual precipitation is compared to "normal" or average precipitation for time periods ranging from 1 to 12 or more months. Actual precipitation departures are normally compared to expected or average amounts on a monthly, seasonal, annual, or water year (October–September) time period. One of the principal difficulties with this (or any) index is the choice of the threshold below which the deficiency of precipitation must fall (e.g., 75% of normal) to define the onset of drought. Thresholds are usually chosen arbitrarily. In reality, they should be linked to impact. Many indices of drought are in widespread use today, such as the decile approach (Gibbs, 1967; Lee, 1979; Coughlan, 1987) used in Australia, the Palmer Drought Severity Index and Crop Moisture Index (Palmer, 1965 and 1968) in the United States, and the Yield Moisture Index (Jose et al., 1991) in the Philippines and elsewhere. For a comparison of several popular meteorological indices, see Olidapo (1985).

Another distinguishing feature of drought is its duration. Droughts usually require a minimum of 2–3 months to become established but then can continue for several consecutive years. The magnitude of drought impacts is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event. The 5-year (1979–83) drought in northeast Brazil is a good case in point. In this series of years, 1979 and 1980 were both drought years in the classic sense (i.e., a significant deficiency during the principal rainy reason). In 1981, the seasonal rainfall totals were slightly above normal but the temporal distribution resulted in agricultural drought. In 1982, the opposite pattern occurred (meteorological drought), and the results were less adverse for agriculture. These 4 "drought" years were followed by the most severe drought year (1983) of the previous 25 years (Magalhães et al., 1988).

Droughts also differ in terms of their spatial characteristics. The areas affected by severe drought evolve gradually, and regions of maximum intensity shift from season to season. In larger countries, such as Brazil, China, India, the United States, or Australia, drought would rarely, if ever, affect the entire country. During the severe drought of the 1930s in the United States, for example, the area affected by severe drought never exceeded 65% of the country (see fig. 1). In India, the droughts of this century have rarely affected more than 50% of the country. An exception occurred in 1918–19, when 73% of the country was affected (Sinha et al., 1987). On the other hand, it is indeed rare for drought *not* to exist in a portion of these countries in every year. For example, figure 1 illustrates that in the United States the percent area affected by drought is often greater than 10%. Thus, the governments of these larger countries are more accustomed to dealing with water shortages and have established an infrastructure to respond, albeit reactively. For smaller countries, it is more likely that the entire country may be affected since droughts are usually regional phenomena—they result from large-scale anomalies in atmospheric circulation patterns that become established and persist for periods of months, seasons, or longer.

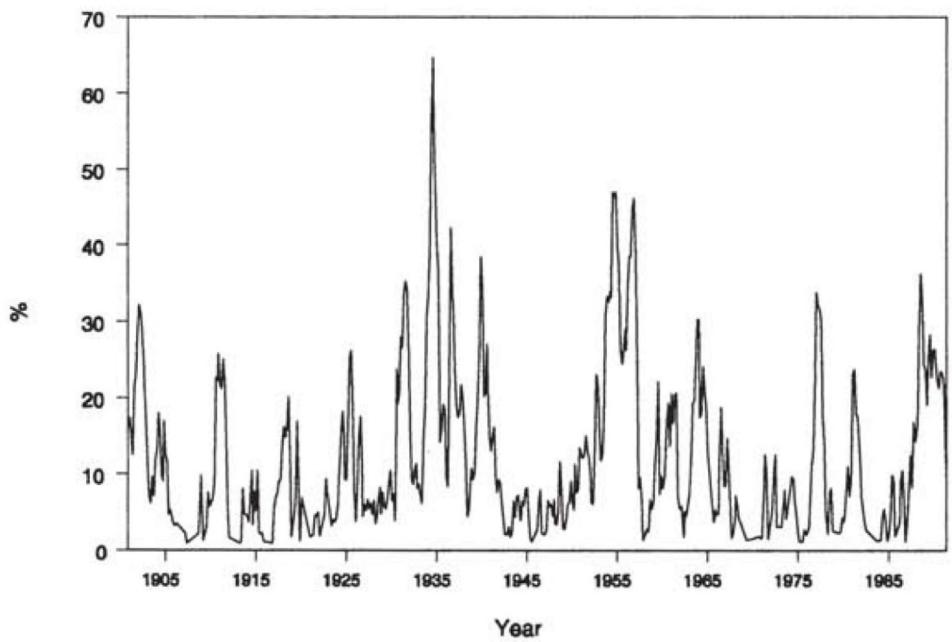

Figure 1. Percent area of the United States experiencing drought, 1895–1991. Compiled from data provided by the National Climatic Data Center, National Oceanic and Atmospheric Administration, Asheville, North Carolina, U.S.A.

From a planning perspective, the spatial characteristics of drought have serious implications. Nations should know the probability that drought may simultaneously affect all or several major crop-producing regions within their borders and develop contingencies if such an event were to occur. Likewise, it is important to know the chances of a regional drought simultaneously affecting agricultural productivity in their country as well as adjacent or nearby nations on whom they are dependent for food supplies. In some instances, a nation's primary drought mitigation strategy may be to import food from nearby nations, ignoring the likelihood that a drought may have significant regional impacts. Likewise, the occurrence of drought worldwide or in the principal grain exporting nations, such as occurred during the ENSO event of 1982–83 (Glantz et al., 1987; Glantz et al., 1991), may significantly alter a developing country's access to food from donor governments.

Impacts of Drought

The impacts of drought are diverse and often ripple through the economy. Thus, impacts are often referred to as direct or indirect, or they are assigned an order of propagation (i.e., first-, second-, or third-order) (Kates, 1985). Conceptually speaking, the more removed the impact from the cause, the more complex its link to the cause. In other words, a loss of yield resulting from drought is a direct or first-order impact of drought. However, the consequences of that impact (e.g., loss of income, farm foreclosures, outmigration, government relief programs) are secondary or tertiary impacts. First-order impacts are usually of a biophysical nature while higher-order impacts are usually associated with socioeconomic valuation, adjustment responses, and long-term "change." Asfaw (1989) succinctly summarized drought impacts as "direct or indirect, either singular or cumulative, immediate or delayed."

Because of the number of affected groups and sectors associated with drought, the geographic size of the area affected, and the difficulties connected with quantifying environmental damages and personal hardships, the precise determination of the financial costs of drought is an arduous task. Average annual estimates of the direct losses attributable to drought are misleading. Although some drought-related costs and losses may occur each year in some countries, in most instances they tend to occur in clusters around major single- or multiple-year events. Therefore, direct and indirect losses may be extremely large for one or two consecutive years and then negligible for several years. This clustering of drought-related costs and losses is repeated over and over again. For example, northeast Brazil experienced a severe drought from 1979 to 1983 that was preceded and followed by a series of favorable or wet years. The same can be said for Kenya, 1983-84 (Downing et al., 1987); Zimbabwe, 1981-84 (Makarau and Marume, 1989); Botswana, 1979-80 (Moremi, 1987); and India, 1980-82 (Sinha et al., 1987) and 1988-89 (Venkateswarlu, 1992). The ebb and flow of dry and wet years (and thus the drought-related costs and losses) hinders the preparedness process in all countries. Human nature is to assume that next year will be a "good" year.

The impacts of drought can be classified into three principal sectors: economic, environmental, and social. Table 1 illustrates the principal impacts associated with each of these sectors. The economic impacts of drought are numerous, ranging from direct losses in the broad agricultural and agriculturally related sectors, including forestry and fishing, to losses in recreation, transportation, banking, and energy. Other economic impacts would include added unemployment, increases in food prices and overall disruption of food supply, strain on financial institutions because of farm foreclosures, increased costs of new or supplemental water resource development, and loss of revenue to local, state, and federal government. Environmental losses are the result of damages to plant and animal species, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; and soil erosion. These losses are difficult to quantify, but growing public awareness and concern for environmental quality has forced public officials to focus greater attention on this problem. Increasing levels of environmental regulation (e.g., water quality, preservation of wildlife habitat) have imposed a new layer of constraints on water managers during water-short periods. This trend is likely to continue. Social impacts mainly involve public safety, health, conflicts between water users, inequities in the distribution of impacts and disaster relief programs, loss of life, increased social unrest, depopulation of rural areas, and reduced quality of life.

Table 1. Classification of drought-related impacts (modified from Wilhite, 1993)

Problem Sectors	Impacts
Economic	loss from crop production
	annual and perennial crop losses; damage to crop quality
	reduced productivity of cropland (wind erosion, etc.)
	insect infestation
	plant disease
	wildlife damage to crops
	loss from dairy and livestock production
	reduced productivity of rangeland
	forced reduction of foundation stock
	closure/limitation of public lands to grazing
	high cost/unavailability of water for livestock
	high cost/unavailability of feed for livestock
	high livestock mortality rates
	increased predation
	range fires
	loss from timber production
	forest fires
	tree disease
	insect infestation
	impaired productivity of forest land
	loss from fishery production
	damage to fish habitat
	loss of young fish due to decreased flows
	loss of national economic growth, retardation of economic development
	income loss for farmers and others directly affected
	loss from recreational businesses
	loss to manufacturers and sellers of recreational equipment
	increased energy demand and reduced supply because of drought-related power curtailments
	costs to energy industry and consumers associated with substituting more expensive fuels (oil) for hydroelectric power
	loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, etc.)
	decline in food production/disrupted food supply
	increase in food prices
	increased importation of food (higher costs)
	unemployment from drought-related production declines
	strain on financial institutions (foreclosures, greater credit risks, capital shortfalls, etc.)
	revenue losses to federal, state, and local governments (from reduced tax base)

	revenues to water supply firms
	revenue shortfalls
	windfall profits
	loss from impaired navigability of streams, rivers, and canals
	cost of water transport or transfer
	cost of new or supplemental water resource development
Environmental	damage to animal species
	wildlife habitat
	lack of feed and drinking water
	disease
	increased vulnerability to predation (e.g., from species concentration near water)
	wind and water erosion of soils
	damage to fish species
	damage to plant species
	water quality effects (e.g., salt concentration)
	air quality effects (dust, pollutants)visual and landscape quality (dust, vegetative cover, etc.)
Social	food shortages (decreased nutritional level, malnutrition, famine)
	loss of human life (e.g., food shortages, heat)
	public safety from forest and range fires
	conflicts between water users
	health-related low flow problems (e.g., diminished sewage flows, increased pollutant concentrations, etc.)
	inequity in the distribution of drought impacts/relief
	decreased living conditions in rural areas
	increased poverty
	reduced quality of life
	social unrest, civil strife
	population migration (rural to urban areas)

Summary

Drought is, indeed, a complex and poorly understood phenomenon that affects more people than any other natural hazard. Impacts are far-reaching and may linger for months or even years beyond the termination of the event. The economic, social, and environmental impacts of drought result from complex interactions between physical and social systems that are difficult to quantify. Scientists and policy makers must understand the characteristics of drought and appreciate the magnitude and complexity of impacts in order for viable assessment and response strategies to be established. The aim of these strategies is to reduce societal vulnerability to periods of water shortages.

About the Author

Donald A. Wilhite is professor of agricultural climatology in the Department of Agricultural Meteorology and director of the International Drought Information Center at the University of Nebraska–Lincoln. He specializes in studies of the impact of climate on society and societal response to climatic events, particularly drought. Dr. Wilhite is coeditor of

Planning for Drought: Toward a Reduction of Societal Vulnerability, published by Westview Press in 1987. He has recently written a guidebook on drought preparedness for developing countries under sponsorship of the United Nations Environment Program. Dr. Wilhite is chair of the Committee on Applied Climatology of the American Meteorological Society.

References

American Heritage Dictionary. 1976. Houghton Mifflin, Boston.

Asfaw, D. 1989. Drought preparedness in Ethiopia. Unpublished paper. Drought Management and Preparedness Training Seminar for Eastern and Southern Africa. Gaborone, Botswana.

Coughlan, M. J. 1987. Monitoring drought in Australia. *In* D. A. Wilhite and W. E. Easterling, eds. *Planning for Drought: Toward a Reduction of Societal Vulnerability;* Chapter 10. Westview Press, Boulder, Colorado, U.S.A.

Downing, T. E.; K. W. Gitu; and C. M. Kamau, eds. 1987. *Coping with Drought in Kenya: National and Local Strategies.* Lynne Rienner Publishers, Boulder, Colorado, U.S.A.

Dracup, J. A.; K. S. Lee; and E. G. Paulson, Jr. 1980. On the definition of droughts. *Water Resources Research* 16(2):297–302.

Gibbs, W. J.; and J. V. Maher. 1967. *Rainfall Deciles as Drought Indicators.* Bureau of Meteorology Bulletin No. 48. Melbourne, Australia.

Glantz, M. H.; and R. W. Katz. 1977. When is a drought a drought? *Nature* 267: 192–93.

Glantz, M. H.; R. W. Katz; and M. Krenz. 1987. *Climate Crisis: The Societal Impacts Associated with the 1982–83 Worldwide Climate Anomalies.* National Center for Atmospheric Research, Boulder, Colorado, U.S.A.; and U.N. Environment Program.

Glantz, M. H.; R. W. Katz; and N. Nicholls. 1991. *Teleconnections Linking Worldwide Climate Anomalies.* Cambridge University Press, Cambridge.

Hagman, G. 1984. *Prevention Better than Cure: Report on Human and Natural Disasters in the Third World.* Swedish Red Cross, Stockholm.

Jose, A. M.; F. O. Magnayon; and F. D. Hilario. 1991. Climate impact assessment for agriculture in the Philippines. Unpublished paper. National Workshop on Drought Planning and Management in the Philippines. Quezon City, Philippines.

Kates, R. W. 1985. The interaction of climate and society. *In* R. W. Kates, J. H. Ausubel, and M. Berberian, eds. *Climate Impact Assessment*; Chapter 1. John Wiley and Sons, New York.

Klemeš, V. 1987. Drought prediction: A hydrological perspective. In D. A. Wilhite and W. E. Easterling, eds. *Planning for Drought: Toward a Reduction of Societal Vulnerability;* Chapter 7. Westview Press, Boulder, Colorado, U.S.A.

Lee, D. M. 1979. Australian drought watch system. *In* M. T. Hinchey, ed. *Botswana Drought Symposium*; pp. 173–87. Botswana Society, Gaborone, Botswana.

Magalhães, A. R.; H. C. Filho; F. L. Garagorry; J. G. Gasques; L. C. B. Molion; M. da S. A. Neto; C. A. Nobre; E. R. Porto; and O. E. Rebouças. 1988. The effects of climatic variations on agriculture in Northeast Brazil. *In* M. L. Parry, T. R. Carter, and N. T. Konijn, eds. *The Impact of Climatic Variations on Agriculture.* Vol. 2, *Assessments in Semi-Arid Regions;* pp. 273–380. Kluwer Academic Publishers, Boston.

Makarau, A.; and W. Marume. 1989. Drought management in Zimbabwe: The 1981–85 experience. Unpublished paper. Drought Management and Preparedness Training Seminar for Eastern and Southern Africa. Gaborone, Botswana.

Moremi, T. C. 1987. Drought planning and response: Botswana experience. *In* D. A. Wilhite and W. E. Easterling, eds. *Planning for Drought: Toward a Reduction of Societal Vulnerability;* Chapter 26. Westview Press, Boulder, Colorado, U.S.A.

Olidapo, E. O. 1985. A comparative performance analysis of three meteorological drought indices. *Journal of Climatology* 5:655–64.

Palmer, W. C. 1965. *Meteorological Drought.* Research Paper No. 45. U.S. Weather Bureau. Washington, D.C.

Palmer, W. C. 1968. Keeping track of crop moisture conditions, nationwide: The new crop moisture index. *Weatherwise* 21(4):156–61.

Sandford, S. 1979. Towards a definition of drought. *In* M. T. Hinchey, ed. *Botswana Drought Symposium.* Botswana Society, Gaborone, Botswana.

Sinha, S. K.; K. Kailasanathan; and A. K. Vasistha. 1987. Drought management in India: Steps toward eliminating famines. *In* D. A. Wilhite and W. E. Easterling, eds. *Planning for Drought: Toward a Reduction of Societal Vulnerability;* Chapter 27. Westview Press, Boulder, Colorado, U.S.A.

Subrahmanyam, V. P. 1967. *Incidence and Spread of Continental Drought.* WMO/IHD Report No.2. WMO, Geneva.

Tannehill, I. R. 1947. *Drought: Its Causes and Effects.* Princeton University Press, Princeton, New Jersey, U.S.A.

Venkateswarlu, J. 1992. Disaster management: A national perspective. *Drought Network News* 4(1):4–6. International Drought Information Center, University of Nebraska, Lincoln, Nebraska, U.S.A.

Whipple, W., Jr. 1966. Regional drought frequency analysis. *Proceedings of the American Society of Civil Engineers* 92(IR2): 11–31.

Wilhite, D. A.; and M. H. Glantz. 1985. Understanding the drought phenomenon: The role of definitions. *Water International* 10:111–20.

Wilhite, D. A.; N. J. Rosenberg; and M. H. Glantz. 1986. Improving federal response to drought. *Journal of Climate and Applied Meteorology* 25:332–42.

Wilhite, D. A. 1992. Drought. *Encyclopedia of Earth System Science,* Vol. 2; pp. 81–92. Academic Press, San Diego, California, U.S.A.

Wilhite, D. A. 1993. *Preparing for Drought: A Guidebook for Developing Countries.* United Nations Environment Program, Nairobi, Kenya (in press).

World Meteorological Organization. 1975. *Drought and Agriculture.* WMO Technical Note No. 138. Report of the CAgM Working Group on the Assessment of Drought. WMO, Geneva.

Yevjevich, V. 1967. *An Objective Approach to Definitions and Investigations of Continental Hydrologic Droughts.* Hydrology Papers No. 23, Colorado State University, Fort Collins, Colorado, U.S.A.